# Proceedings

# Micro-CHP Technologies Workshop

Greenbelt, Maryland
June 11-12, 2003

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U.S. Department of Energy
Energy Efficiency and Renewable Energy

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# Chapter 1. Introduction

On June 11-12, 2003, more than 50 stakeholders from industry, government agencies, universities and other organizations involved in combined heat and power (CHP) and the residential buildings industry participated in a *National Micro-CHP Technology Pathways Workshop* in Greenbelt, Maryland. The participants met in a facilitated 1 ½ day workshop to envision a desired future for Micro-CHP systems and to develop a strategy to achieve this vision. The focus of the workshop was to create a pathway for technology research, development and demonstration (RD&D) for Micro-CHP systems. Participants were tasked to identify technology cost and performance targets that can be achieved by 2010; a priority list of RD&D needs to reach the targets; and a specific list of next steps for defining technology pathways to reach the targets.

This document is a summary of workshop proceedings. It captures the comments and ideas that were exchanged, and summarizes the major themes that were expressed throughout the workshop.

The plenary session provided participants with a common understanding of the scope of the technology pathways process. It included an overview of Micro-CHP technologies and markets, both domestic and international, and identified expected workshop products. Copies of the presentations may be found at www.energetics.com/microchp.html Participants also discussed the overall goal of Micro-CHP:

*To develop clean, cost-effective, commercially available Micro-CHP systems in the United States residential marketplace by 2010.*

Participants were then divided into three parallel breakout sessions (Yellow, Orange, and Blue). The breakout sessions met concurrently and each with a similar number and composition of individuals. Each breakout group addressed the following questions:

- What technology cost and performance targets have to be achieved to develop commercially available, clean, efficient, affordable micro-CHP systems for the United States residential marketplace by 2010?
- What research, development, demonstration and technology transfer needs to be done to reach the technology cost and performance targets?
- What pathways will accomplish the top priority needs?

The summary session at the end of the workshop allowed the entire group to hear the results of each breakout session and to engage in a discussion on the findings of each group, provide concluding remarks and suggest next steps. The breakout group presentations may also be found online at www.energetics.com/microchp.html

# Chapter 2. Overall Goal for Micro-CHP

Participants were asked to give feedback on the Overall Goal:

*To develop clean, cost-effective, commercially available Micro-CHP systems in the United States residential marketplace by 2010*

Many participants thought that the year 2010 was under-ambitious. They believe that clean, cost-effective, commercially available Micro-CHP systems could be available before 2006. Others thought 2010 was suitable and maybe even over-ambitious.

Due to the diversity of U.S. climate zones and markets, Micro-CHP systems need to address these specific markets. Cooling needs to be included in Micro-CHP systems, so these systems have the potential to meet customer needs in any U.S. climate zone. The development of these systems must focus on customer requirements (i.e. thermal and electric loads, reliability, versatility, environmentally friendly, etc.)

The infrastructure must be developed for Micro-CHP systems to successfully reach the market. Interconnection issues have to be resolved so these systems can connect to the local utility. The development of codes and standards will clearly define levels of "clean" and "efficient".

Finally, Micro-CHP systems should be recognized as "appliances". The complete list of suggestions/comments on the goal can be found in Table 2.1.

Therefore, the revised overall goal or "vision" for Micro-CHP systems is:

*By 2010, environmentally friendly, cost-effective, versatile, reliable, fuel flexible, Micro-CHP appliances will be commercially viable for the* ***entire*** *United States residential marketplace.*

- CHP includes heating, cooling, and power
- Includes infrastructure development (utility interconnection, supply chain, standards, etc)
- Addresses national energy priorities (energy efficiency, environmental emissions, fuel diversity, energy assurance)

## TABLE 2.1 FEEDBACK ON OVERALL GOAL

- Define residential market
  - Affluent
  - Multi-family
  - Urban
  - Rural
- Lump attributes as: Residential CHP Appliance (image)
- Packaged system
- Versatility
- Needs a metric on size of market in 2010: # units/# KW/GW installed
- Multi-fuel capable
- Fuel flexible, high efficiency
- Develop and demonstrate commercially viable micro-CHP
- Optimum path to market needs discussion
- With high efficiency resource efficiency
- MCHP should include consideration of providing cooling
- Is the goal of the program to have a certain % of residential building using CHP?
- We need to quantify clean and cost effective
- Define cost-effective
- Define clean in the context of U.S. Emission profiles
- User Friendly - Bigger E/T = smaller T/E
- Focus on customer requirements
- Make sure the market is ready for CHP
- Economically viable
- Cost effective
  - Value of standby power
  - True cost of displaced power
- Viable
- Here "today"
- Require more clear definition of payback
- Faster 2006 portable
- Only if the problem with interconnection is solved
- 2010? Why not 2004? Why not now? M-CHP is financially viable now. 16 cents/kWh in NYC
- Too generalized why not just demo? 2006 not 2010. Need additional market research – customer requirements
- Change 2010 to 2005-2006
- Need earlier date 2007 for private sector
- Extend timeframe to 2015/2020
- Should target energy-efficient house market: unit designed with future loads in mind (energy efficient first)
- Need to define/differentiate "U.S." market, e.g., cooling stand-alone
- Good overall target, might want to provide time steps for different markets
- Ambitious goal – 2010 – great – technology – demonstration
- Under ambitious
- Unlike Europe. First competition 2008 (1) for the majority of residential applications by 2010, (2) back-up HVAC – various
- Include "cooling' in goal, so it becomes micro-CHPC
- Include renewable systems that displace electric power
- Cooling grid/nongrid
- Cooperation with other home appliance. Manufacturers
- Integrated efficient
- Reliable
- In addition to product development, there must be infrastructure development to support benefits. Also, need to change mindset and capability of builders and installers
- Goal focused on RD&D – need viable business models, too.
- It is unclear to me what "clean" means as most of the technologies looked at release pollution while operating
- Define "Clean" - #2 fuel oil, $NO_x$ other emissions
- Needs definitions of clean, cost effective and commercialism available
  - Shorten timeframe

# Chapter 3. Breakout Group Yellow

The key themes and messages that set the stage for discussion about Micro-CHP RD&D and technology transfer strategies include:

- Micro-CHP appliances must address market needs and have viable business models to successfully transfer the technology from the development stages to the market place.
- Achieving the cost and performance targets will require close collaboration with utilities and builders.
- DOE needs to clarify the desired national benefits for Micro-CHP appliances.

**Participants: Yellow Group**

| NAME | ORGANIZATION |
|---|---|
| Bob Alvarez | Lennox, Ind |
| Ed Barbour | NCI |
| Ted Bronson | Power Equipment Associates |
| Dale Dietzel | U.S. DOE |
| Mike Duhamel | Marathon Engine Systems |
| Charles Garland | Columbus Circle Power Systems |
| Patti Garland | ORNL |
| Joseph Gerstmann | AMTI |
| Leon Gielen | Enatec Micro Cogen |
| Jeremy Harrison | EA Technologies |
| Pat Hoffman | U.S. DOE |
| Eli Hopson | Science Committee, US House of Representatives |
| Tom Reed | Climate Energy |
| Michael Sahm | UTCR |
| Dave Sutula | GAMA |
| Bob Zogg, Spokesperson | Tiax, LLC |

*** Report Out Presenter**

**FACILITATOR:** RICH SCHEER, ENERGETICS, INCORPORATED

The technology cost and performance targets and the RD&D needs to achieve these targets were discussed under the following premises and assumptions:

- Both thermal and electric load following systems are needed
- Single family residences are the primary focus
- The devices are prime mover and fuel neutral
- Should desirable Micro-CHP appliances be made available to customer, the market infrastructure is set to adopt then

The various markets - vintage, climate zones, location, building types- will determine the specifications for technology development. Some of the cross-cutting market technology cost and performance targets must address:

- *Efficiency*. These targets have to weigh the relative value of electricity, heating, and cooling.
- *Output-based emission targets*
- *System design*, which includes architecture for interoperability.
- *Cost*. Three year payback with no “shock” cost.

A complete list of the technology cost and performance targets for the yellow breakout group can be found in Table 3.1

The top priority RD&D and technology transfer needs are:

- Develop “home load management” control systems
- Develop measurable performance benchmarks
- Develop energy storage devices
- Conduct market assessment to define customer requirements
- Develop and demonstrate packages systems for target markets and regions

The complete list of RD&D and technology transfer needs can be found in Table 3.2.

Developing home load management control systems would act as a “whole house controller”- prioritizing loads, deferring discretionary loads, even acting as a “broker” selling and buying power as needed. This activity would build on European activities and include collaboration with National Association of Home Builders (NAHB), national labs, utilities, code officials, and A/E firms.

Developing measurable performance benchmarks would let the various micro-CHP appliances compete on the same playing field. Test procedures would be developed for noise, emissions, thermal and electric output/efficiency, and financial indicators (payback, installed cost, etc). These test procedures could be approved regionally and will require 3rd party verification.

Developing thermal and electrical energy storage devices compatible with Micro-CHP appliances will increase the system’s performance. The first step in developing energy storage devices is to define system specifications: size, load, profile, and storage requirements. The next step is to assess the various storage technologies for that specific Micro-CHP appliance. It is important to notice that different appliances will require different storage devices.

A thorough market assessment for Micro-CHP appliances is needed to define customer needs and expectations. This could be the first step in defining Micro-CHP appliance requirements. A survey could be conducted and the results analyzed and available to the public.

Developing and demonstrating cost-effective Micro-CHP packaged systems is extremely important. These demonstrations will be targeted at specific markets and regions. They will result in evaluations of the prime movers, heating and cooling operations, and ultimately an optimally designed system.

A complete list of Paths Forward may be found in Table 3.3

## TABLE 3.1 TARGETS

| MARKET SEGMENTATION – SPECIFICATIONS FOR TECHNOLOGY DEVELOPMENT | SYSTEM DESIGN | EFFICIENCY | EMISSIONS |
|---|---|---|---|
| **A. Vintage**<br>• Existing Buildings<br>– Typically installed for emergency replacement<br>– Must be readily available<br>– Must have retro-fit value-added<br>– Efficiency could be selling point<br>• New Construction<br>– Most new homes built in the South<br>– Cooling needs will have to be addressed<br>– Forced-air dominates<br>– Get in at design/architectural phase<br>– Low-cost is selling point<br>**B. Climate Zone**<br>• Long Winters-High Heating Loads<br>– Heating/hot water needs<br>– Value for standby power<br>• Hot/Humid Summers – High Cooling Loads<br>– Cooling, humidity control<br>– Swimming pools<br>– Higher E/T ratios<br>• Mixed<br>– System flexibility<br>– Tune to the season<br>**C. Location**<br>• Rural<br>– Access to propane, biomass, diesel, fuel oil<br>– Grid isolation more likely<br>– High value for standby power<br>• Urban<br>– Low cost a primary driver<br>– Environmental emissions major concern<br>– Noise a major concern<br>– Footprint a major concern<br>– Opportunity for micro-grid<br>**D. Building Type** | • Have packaged systems for retrofit and new construction<br>• Key Design Features of Packaged Systems<br>– Simple to install and operate<br>– Modular<br>– Fuel flexible<br>– Standardized approach<br>• Time Table<br>– Immediate implementation of existing systems for demonstrations in niche markets (e.g. affluent residences with built-in swimming pools)<br>– Systems for retrofit applications in 5 years<br>• Straight Payback Period<br>– 10 yr by 2004<br>– 5-7 yr by 2007<br>– 3-5 yr by 2010<br>• Associated Cost Payback Period<br>– 15 yr by 2004<br>– 7-20 yr by 2007<br>– 3-5 yr by 2010 | • Heat "Value" = 1; Cool "Value" = 1; Electricity "Value" = 3<br>• By 2006 Achieve performance metric of 1.4<br>• By 2010 performance value of 1.8<br>• Beware not to set target as to predetermine type of technology | • Air Emissions<br>– By 2005/08/12<br>– Meet output based rules for NOx, $CO_2$, CO, particulates<br>– Similar to RAP Model Rules or those used in NY or CA<br>• Noise/Vibrations<br>– By 2005, must be acceptable to typical residential user<br>• Environmental Management System<br>– Establish by 2005 for water, land use, life-cycle impacts<br>• Pre-certification Guidelines<br>• Establish by 2005 |

| Market Segmentation – Specifications for Technology Development | System Design | Efficiency | Emissions |
|---|---|---|---|
| • Single Family Detached<br>– More electric use<br>– More thermal use<br>– Larger footprint accepted<br>• Single Family Attached<br>– Same as low rise<br>• Low-rise Multi-Family (3 stories or less)<br>– Lower electric and thermal requirement per unit<br>– More opportunities for aggregation<br>**E. Time Frame**<br>• Favorable Near Term<br>– New construction<br>– Long winters<br>– Single family detached, high value for standby power<br>– Rural<br>– Affluent<br>• Long Term<br>– Utility involvement for peak reduction<br>**F. General Issues**<br>• Have net metering<br>• Resolve siting issues<br>• Ability to take advantage of real-time utility pricing<br>• Attaining system flexibility for multiple markets<br>• Adjusting to predominance of forced air<br>• Marketing: “Power Appliance” | | | |

## Table 3. 2 RD&D and Technology Transfer Needs

♦ High priority needs

| Technology and Market Analysis | Component Technologies | Control Systems | Packaged and Systems Integration | Codes and Standards | Coordination and Technology Transfer | Public Policies |
|---|---|---|---|---|---|---|
| • Assess market demand requirements ♦♦♦♦♦<br>– Including customer needs and their expectations for CHP regarding price, performance, and reliability<br>• Define measurable performance benchmarks for efficiency, emissions, payback, and installed costs ♦♦♦♦♦<br>– Define an approach for characterizing system efficiency that is easy for consumers to understand<br>• Assess business models to define most promising applications and overcome market barriers ♦♦♦<br>• Conduct feasibility studies to identify most promising | • Develop affordable thermal and electric storage devices compatible for packaged micro-CHP systems ♦♦♦♦♦<br>• Develop cost-effective and efficient thermally activated technologies for residential applications ♦♦♦♦<br>• Develop power conditioning equipment ♦♦♦<br>– Improved part load efficiency<br>– Lower cost<br>– Higher reliability<br>• Develop appliances and equipment that use DC power ♦♦<br>• Develop cleaner and more efficient recip engine systems ♦♦<br>• Develop low-cost and efficient A/C generator ♦<br>• Develop higher | • Develop a home load management system ♦♦♦♦♦<br>– To prioritize loads<br>– Defer discretionary loads<br>– Manage buy/sell decisions<br>– "Whole House" Controller<br>• Develop self-diagnostic systems ♦♦<br>– Fault detection<br>– Maintenance needs<br>– Efficiency/performance monitoring<br>• Agile demand-load following controls ♦♦<br>• Develop Sensors and controls to detect grid stress<br>– Trigger power export to support the grid | • Investigate methods for manufacturing cost reductions ♦♦♦<br>• Develop and demonstrate packaged systems ♦♦♦<br>– Heating and power<br>– Cooling and power<br>– Heating, cooling and power<br>• Develop dynamic adaptable E/T configured systems ♦♦<br>• Explore all possible integration schemes<br>• Design more affordable residential systems | • Develop national interconnection standards ♦♦♦<br>• Define interconnection protocols for net metering ♦<br>• Develop certification program for unit efficiency to ensure performance comparisons are fair and accurate ♦<br>– Standardized performance metrics for "apples to apples" comparisons<br>• Establish trade group to facilitate standardization process | • Work with appliance equipment manufacturers to foster quick development and identify synergies (e.g. refrigeration) ♦♦♦<br>• Cooperate with European Union on technology and development ♦♦♦<br>• Work with electric and gas utilities ♦♦♦<br>• Educate mass consumer markets ♦<br>• Engage builders and DOE's Build America Program ♦<br>– Share case studies<br>• Buy existing systems and install them on DOE facilities<br>• Obtain access to already funded and relevant DOE research results<br>• Develop industry R&D consortia for pre-competitive activities<br>• Recognize Intellectual | • Obtain RD&D funding to accelerate development timetables ♦♦♦<br>• Incentives/ mandates for utility involvement ♦♦<br>– Encourage utility acceptance of net metering<br>– Develop electric distribution incentivization strategy<br>• Financial incentives ♦<br>– DG/CHP rates e.g., well-head plus 0.5 cents<br>– Finance equipment at proposed savings less a predetermined % of savings<br>– Utility bond authority for several thousand installations<br>– Tax rebate for micro-CHP installations |

| Technology and Market Analysis | Component Technologies | Control Systems | Packaged and Systems Integration | Codes and Standards | Coordination and Technology Transfer | Public Policies |
|---|---|---|---|---|---|---|
| markets and technologies<br>♦♦♦<br>– Examine cost/efficiency trade-offs<br>– Determine system size ranges<br>• Assess impacts on electric and natural gas distribution systems<br>♦♦♦<br>• Assess commercial implementation issues (e.g., metering, training) | efficiency Stirling engines<br>♦<br>• Develop a 2-pipe indoor/outdoor HVAC interface<br>• Develop efficient shaft-driven A/C compressor with variable displacement | | | | Property concerns | |

## TABLE 3.3 PATHS FORWARD

| TOP VOTE GETTING RD&D NEED | "SOUNDBITE" DESCRIPTION | TASKS/ MILESTONES | PARTICIPANTS (PRIMARY SPONSORS/ PERFORMERS) | IMMEDIATE NEXT STEPS |
|---|---|---|---|---|
| Develop and demonstrate cost-effective packaged systems | Packaged Micro-CHP for targeted markets and regions | • Market analysis<br>• Prime mover evaluation<br>• Heating/cooling evaluation<br>• Optimize system design for cost effectiveness<br>• Select site(s)l<br>• Install, operate, monitor<br>• Evaluate/disseminate data | • National labs<br>• Industry labs (e.g. GTI)<br>• Home builders<br>• Equipment manufacturers<br>• Codes and standards groups | • Conduct market study<br>• Issue solicitation for installations |
| Develop energy storage devices compatible with Micro-CHP systems | Electrical and Thermal Storage will Increase System Performance | • Define system (size, load profile, operating strategy, storage reqs)<br>• Assess storage technologies for suitability (best in class)<br>• Design system(s)<br>• Field test prototypes | • Manufacturers<br>• Home builders<br>• End-users | • Initiate project |
| Conduct assessment of market demand requirements including customer needs and expectations | Market Research – The First Step in Defining Micro-CHP Requirements | • Develop Micro-CHP description alternatives<br>• Conduct surveys<br>• Analyze results<br>• Publish results | • DOE sponsorship<br>• Manufacturers and market research firms<br>• Provide results to industry, utilities, end-users | • Issue solicitation |
| Develop home load management system to prioritize loads, defer discretionary loads, manage buy/sell decisions | Whole House Controller | • Define functional requirements<br>• Define system architecture for interoperability and degree of open/proprietary | • National Association of Home Builders<br>• National Labs<br>• Utilities<br>• Architects/building engineers<br>• Code officials<br>• European Community | • Conduct surveys/interviews of appliance and DG trends<br>• Conduct workshops with control system developers<br>• Define win-win proposition for interfacing with utilities |
| Develop measurable benchmarks for systems performance (e.g., payback, emissions, installed cost) including an approach for measuring system efficiency | Apples-to-Apples | • Develop test procedures for noise, emissions, thermal and elec output/efficiency<br>• Get test procedures approved regionally<br>• Develop a certification program for 3rd party verification | • Manufacturers<br>• Testing agencies<br>• Standards orgs<br>• Trade associations<br>• Code officials | • Draft "strawperson"<br>• Finalize standards through ANSI process<br>• Educate local code officials |

# Chapter 4. Breakout Group Orange

There are a number of short-term strategic targets which must be met to bring commercially-available, clean, efficient, affordable Micro-CHP systems to market in the US residential sector. Due to the diverse nature of Micro-CHP appliances, these strategic targets must focus on the end points of both making products commercially available and integrating them into a residential home. The targets must also serve to forward the entire field of Micro-CHP instead of specific technologies or products, as potential markets are still largely undefined and the range of applications varies widely.

**Participants: Orange Group**

| NAME | ORGANIZATION |
|---|---|
| Eric Guyer* | Cilmate Energy |
| Rich Sweetser | Exergy Partners |
| Gary Papas | Marathon Engine |
| Chuck Berry | GTI |
| Michael Hopper | Powerplay Energy |
| Bill Bezilla | Honda R&D |
| David Ahrens | Navigant Consulting |
| Steve Fischer | ORNL |
| Scott Hutchins | DOE – Northeast |
| Richard Fioravanti | ICF Consulting |
| Ren Anderson | NREL |
| Kamyar Zadeh | Energy CoOpportunity |

*** Report Out Presenter**

**FACILITATOR:** TOM TARKA, ENERGETICS, INCORPORATED

Potential markets for Micro-CHP vary widely based on parameters such as:

- Climate (heating versus cooling appliances)
- Location (power versus heating requirements, backup power applications)
- Building types (resulting in stand-alone versus integrated systems)

This diversity results in a somewhat generic set of technology cost and performance targets which can be applied to any potential Micro-CHP appliance. The targets are primarily focused on meeting or exceeding the performance – environmental, cost, and efficiency – of displaced systems, and the demonstration of specific Micro-CHP technologies in live applications. A full listing of performance and technology cost targets discussed is listed in Table 4.1.

A discussion of RD&D needs, as shown in Table 4.2, led to the conclusion that the primary hurdles to producing a commercially available Micro-CHP product are:

- Ability to prove that Micro-CHP technologies are ready for the market
- Conclusively show they out-perform the technologies they replace
- Make integration/implementation easy
- Remove links to specific fuel sources

The resulting pathways forward, as shown in Table 4.3, are:

- Develop Micro-CHP performance standards
- Demonstrate and rate cooling and heating options
- Identify Minnesota Micro-CHP standards as a guideline
- Develop multi-fuel combustion design

The creation of a standardized set of metrics for the evaluation and comparison of both Micro-CHP and traditional heat and power technologies is the initial step in overcoming the first two hurdles above. It is crucial that these metrics be defined in collaboration with ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) to ensure fair assessments and credibility in the field of heating and cooling. Once completed, traditional and existing Micro-CHP technologies can be evaluated and specific performance targets can be set based on the results.

The testing and demonstration of existing Micro-CHP technologies is integral to the development and deployment of commercial products. By evaluating and rating current technologies, areas of potential improvement can be identified and addressed. Extensive demonstrations are necessary to identify and correct unforeseen issues, generate feedback related to product and feature ideas, and showcase working technologies to potential users. The showcasing and early adoption of technologies is critical to industry's willingness to further develop solutions, as it precedes the greater acceptance of technologies as viable, and proves that these technologies are ready for the market. These demonstrations can also be used to prove that Micro-CHP systems out-perform existing systems.

The adoption of the Minnesota Micro-CHP standards as a guideline is meant to lead towards the adoption of federal Micro-CHP standards which would make it easier to implement and install Micro-CHP appliances in residential homes. A federal standard, as opposed to state standards and codes, is necessary to improve integration.

Lastly, the development of multi-fuel combustion design is necessary de-couple Micro-CHP technologies from specific fuel sources. Doing so separates systems' economic viability from the price of a specific fuel and serves as another way in which Micro-CHP can surpass existing systems.

Industry has improved the cost-effectiveness of Micro-CHP technologies and is confident of its ability to meet technological challenges and targets. Yet, for Micro-CHP products to be readily available in the residential market, a broad range of tasks will need to be accomplished, requiring collaboration among industry, governmental entities, universities, and professional associations. The existence of a technology roadmap and open dialogue will greatly aid in accomplishing this goal.

## TABLE 4.1. TARGETS

| SYSTEM DESIGN | ENVIRONMENTAL PERFORMANCE | COST | EFFICIENCY | MARKET |
|---|---|---|---|---|
| • Support the development of heat recovery (heating & cooling) to have product in 2005 with:<br>– 5 year payback on incremental cost<br>– reduced $CO_2$ over average electricity<br>• large deployment (500+ units) supported by the DOE (2005)<br>• 1,000 units deployed (2007)<br>– 90% heat + power efficiency<br>– emissions better than alternatives | • $CO_2$ & $NO_x$ emissions less than displaced systems (heat + electric)<br>• A definition/metric for the $CO_2$ & $NO_x$ emissions of displaced systems<br>• 2007 CARB emission compliant (California compliant)<br>• Noise below current air conditioner or heat pump level<br>• Odor/ByProducts at a non-objectionable level | • Market study to determine what cost targets are needed for success (2004)<br>• $1500/kWe incremental cost product for people who are willing to pay a premium (2005)<br>• <$500/kWe incremental cost product for the mass market (2007)<br>• Cooling, Heating, & Power product for <$1000/kWe incremental (2010)<br>• Define metrics for measuring/evaluating the cost of technologies | • As good as State-of-the-Art heat-only appliances + significant additional energy benefits<br>• Better fuel utilization than provided by the utility grid | • Define the Top 5 markets of residential CHP in the US (deliver by: 2/28/04)<br>• Freedom Appliance Website Initiative (3/02/04)<br>• Determine and support market with "Highest Probability" of success<br>• Issue Micro-CHP Roadmap (3/15/04)<br>• Showcase demo's in 5 selected markets (12/31/04)<br>• Define optimal role for DOE/Industry Partnership (2/28/04) |

## TABLE 4.2 RD&D AND TECHNOLOGY TRANSFER NEEDS

♦ HIGH PRIORITY NEEDS

| INTEGRATION | ADVANCED TECHNOLOGIES | DEMO/TESTING | METRICS | COLLABORATION/ CONSORTIA |
|---|---|---|---|---|
| • System integration in new homes (CHPC)<br>• Component Micro-CHPC[1] integration<br>• Packaging of systems for rating as appliance | • On-the-fly multi-fuel combustion design<br>• Integrated controls & relay protection (IEEE 1547)<br>• Oil-free positive displacement expanders (for power production)<br>• Improved heat transfer from low temperature fluids & vapors<br>• Noise/Vibration component development<br>• Combustion research (natural gas)<br>• Low emission or catalytic combustors | • Demonstrate and rate heat recovery cooling and heating options for CHP<br>• Facilitate and minimize risk and liability of demonstration/beta sites<br>• Demonstration of units and "proof of concepts"<br>• To reach targets, DOE demonstrations and other demonstrations (state SBC funds) are needed (delivery by 5/1/04) | • Action plan dealing with the barriers/incentives for<br>– Interconnection<br>– Retail electricity markets<br>– Special N6 tariffs<br>– (delivery by 3/15/04)<br>• Micro-CHP performance standards<br>• Micro-CHP M-O-T (method of testing)<br>• Emission certification by Micro-CHP DOE Lab (delivery by 6/01/04)<br>• Develop Case Studies on various technologies by monitoring the following parameters:<br>– Reliability<br>– Performance<br>– Emissions | • Stakeholders' consortia to provide a voice to DOE and Congress<br>– Manufacturers<br>– Government<br>– Home Manufacturers<br>– Gas Utilities<br>– State Government<br>– State EPA<br>• Heating industry collaboration Micro-CHP center<br>• MicroCHP center at a National Lab (delivery by 3/15/04)<br>• Training of support staff in select markets for:<br>– Installation<br>– Maintenance<br>– Etc.<br>(delivery by 2/28/04)<br>• R&D funds for improving annual application efficiency<br>• Collaboration with associations such as:<br>– ASHRAE<br>– ARI<br>– ARTI<br>to forward:<br>– Compliance with standards<br>– Creating new standards<br>– Collaborative efforts |

1. CHPC: Combined Heat, Power, and Cooling. Adding cooling (A/C) abilities to CHP products.

## TABLE 4.3 PATHS FORWARD

| TOP VOTE GETTER | "SOUNDBITE" | TASKS/MILESTONES | PARTICIPANTS SPONSORS/PERFORMERS | IMMEDIATE NEXT STEPS |
|---|---|---|---|---|
| • Develop Micro-CHP performance standards | • "Setting the Standard" | 1. Collaborate w/ ASHRAE<br>a. Draft Heat & Power (1/05)<br>b. Cooling & Power (12/06)<br>2. ASHRAE/ANSI Std. (2007) | • Manufacturers<br>• Universities<br>• Government | 1. Work w/ ASHRAE TC9.5 – June 2003 meeting<br>2. Identify/recommend SPC members/representatives |
| • Demonstrate and rate heat recovery cooling and heating options for CHP | • "Total Energy Appliance"<br>• "Path to Adoption | 1. Establish demonstration sites at National Labs "Showcase Center"<br>2. Immediate testing of current technologies to identify potential gaps and publish results<br>3. Develop program to facilitate cooling technologies<br>4. Establish sites for large-scale demonstration<br>5. Integrate cooling technologies into existing sites | • DOE<br>• Manufacturers (Current)<br>• National Labs<br>• Government Facilities<br>• State Agencies | • Program outline by DOE |
| • Identify Minnesota Micro-CHP standards as a guideline (was: Action plan dealing with the barriers/incentives) | • "Using the Minnesota Model as a Guide" | 1. Send Minnesota model to all Micro-CHP roadmap participants<br>2. Milestones<br>a. Suggested guide (1/2004)<br>b. FERC proceeding (9/2003) | • FERC<br>• NREL<br>• Others | • Publicize Minnesota model |
| • Develop integrated controls and relay protection | • "Get IEEE 1547 DONE TODAY!" | • Help IEEE finalize 1547<br>• Milestone: Complete by 7/2003 | • NREL<br>• Others | • Encourage adoption by federal energy agencies, TVA, BPA, etc. |
| • Develop multi-fuel combustion design | • "A flexible solution for the home" | 1. Natural Gas Solutions - 2003<br>2. Oil<br>a. All others - 2004<br>b. Clean diesel - 2007<br>3. Bio Fuels<br>a. Bio-diesel - 2005<br>b. Pellets - 2008<br>4. $H_2$ - 2050 | 1. Industry<br>2. Industry / Government<br>3. Government / University<br>4. Government | 1. Continue existing development<br>2. Continue existing development<br>3. Characterize, design, testing<br>4. Funding |

# Chapter 5. Blue Breakout Group

Micro-CHP systems are appliances, just like dishwashers, water heaters, or dryers. In developing these appliances, residential thermal loads are going to be the driving factor in the design of the system. It is important that these systems sufficiently support thermal loads. There will not be one "savior" technology for Micro-CHP appliances. Various systems will use various technologies in an effort to meet consumer demands. It will thus be necessary to develop standards for Micro-CHP appliances, so all systems and technologies compete on a level playing field.

In researching, developing, and demonstrating Micro-CHP technologies it is important to recognize that the U.S. market is very large and diverse allowing creativity in system design. Industry is ready to assemble "alpha" Micro-CHP systems, but more component development may be needed. Many Micro-CHP appliances are now ready for the U.S market.

Micro-CHP appliances must reach the following cost and performance targets to achieve the overall goal.

- Emission levels that are equal to or better than current heating appliances
- Integrated plug and play packages with smart controls
- Paybacks of 5-8 years by 2007 and 3-5 years by 2010

**Participants: Blue Group**

| NAME | ORGANIZATION |
|---|---|
| Rui Afonso | Climate Energy |
| Tom Butcher | Brookhaven National Laboratory |
| Bob Devault | Oak Ridge National Laboratory |
| Evgueniy Entchev | CANMET Energy Technology Center |
| Ray Erbeznik | Stirling Technology Company |
| Bill Ernst | Plug Power |
| Evan Gaddis | GAMA |
| Tom Henkel | Solargenix Energy |
| Mikio Imai | Honda R & D Japan |
| Mark Kendall* | GAMA |
| Chirstian Murphy | CECA |
| Tom Rosfjord | United Technologies Research Center |
| Richard Topping | Tiax, LLC |
| Suzanne Watson | Northeast-Midwest |

*** Report Out Presenter**

**FACILITATOR:** DAN BREWER, ENERGETICS, INCORPORATED

A complete list of technology cost and performance targets may be found in Table 5.1

The top priority RD&D needs to achieve the cost and performance targets are:

- Develop residential scale cooling module
- Conduct R&D on systems integration (electric/heat/cooling)
- Develop system models useful to develop control options and evaluate performance
- Fund pilot programs (10-100's of units) to consortia and have consumers evaluate

- Complete prototypes with high performance, which can be field tested

The entire list of RD&D and technology transfer needs may be found in Table 5.2

Integrating cooling capabilities into Micro-CHP systems is critical for residential applications. Recycled heat drives the cooling process, whether absorption, adsorption, desiccants, or ERV devices. The cooling process is based on cooling load, household thermal needs, configuration, and prime mover performance.

A proof -of -concept residential packaged unit combining heat, power, cooling, and thermal storage, using off-the-shelf components, will be the first step in researching and developing system integration of Micro-CHP systems. This would be a team effort including: power source companies, HVAC companies, controls manufacturers, a project integrator, and a utility.

System models will help develop controls options and evaluate performance of Micro-CHP components. These models will optimize the use of heat and power on a real time basis. A time-dependent modular system model will have various control options, and evaluate economics. The immediate next step is to identify model requirements.

A residential Micro-CHP field demonstration and evaluation program of 10-100's units will provide useful information on the different Micro-CHP appliances. The different technologies would be matched with the appropriate locations and markets. The next step, before field testing, would be to evaluate the readiness and applicability of each Micro-CHP appliance.

Micro-CHP full system development will lead to uniform product requirements, test protocols, standards, performance rating and labeling. These systems will be developed for a defined market, lab evaluated, field tested, and the performance of the systems will be extrapolated to explore other opportunities and applications.

## TABLE 5.1. TARGETS

| SYSTEM DESIGN<br>THESE SHOULD BE MEET THROUGHOUT THE ENTIRE TIME PERIOD | ENVIRONMENTAL PERFORMANCE | COST | EFFICIENCY | MARKET |
|---|---|---|---|---|
| • Plug & play systems<br>• Integrated packages<br>• Use of any fuel that meets environmental targets<br>• CHP with cooling as an option<br>• Thermal/Electric ratio is driven by region<br>• User friendly controls that integrates with standard HVAC controls<br>• Noise vibration, etc. must meet existing residential appliances | • Establish, industry agreed upon, standards for seasonal efficiency labeling (2005)<br>• Achieve equal to or better than emission factors of current heating appliances (g/kg fuel) (2006)<br>• Achieve equal to or better than noise emission of current heating appliances (2006)<br>• Pre- and post-certification program in place (voluntary) (2006) | • Achieve a payback of 5-8 years (2007)<br>• Achieve a pay back 3-5 years (2010)<br>• First cost<br>– 2007 – 2x<br>– 2010 – 3x<br>• Include added benefits:<br>– Environmental<br>– Distribution system<br>– Added benefits | • Efficiency = output/input Conversion from hydrocarbon to useful electrical and thermal energy 1 KWe = 2 kWh (cool), 1 kWe = 3 kWh (heat)<br>For systems 1-15 kWe<br>• By 2007 combined efficiency (LHV), >41% for heating and electric, >51% for cooling and electric<br>• By 2010 conversion efficiency> 45%, >55%<br>— Fuel based well to residence<br>— No incentives<br>— Life cycle product efficiency $\geq$85% | • First step: Understand market potential by 2005<br>– #'s on segment<br>– Size (capacity)<br>– Fuel types<br>– Regional differences<br>– Need for AC<br>– Net metering and power pricing issues<br>– Ownership<br>• Establish goals for outreach and education by 2005<br>• Study role of incentives to accelerate commercialization<br>– Tax credits<br>– Regulation<br>(2005)<br>• Determine who will drive the market (2006)<br>– Consumer risk adverse<br>– CHP → appliance<br>– HVAC contractors<br>– ESCO's<br>• Target "premium power" as an early adopter (2006):<br>– Rural<br>– Vacation<br>– Medical equipment<br>– Multi-fuel<br>• Target new construction (2008)<br>– Financing<br>– Upscale homes<br>– Progressive builders<br>• Establish 10% penetration target by 2010 |

# TABLE 5 2. RD&D AND TECHNOLOGY TRANSFER NEEDS

♦ HIGH PRIORITY NEEDS

| COMPONENTS | INTEGRATION | DESIGNS | DEMO/TESTING | STANDARDS | MARKETS |
|---|---|---|---|---|---|
| • Develop residential scale cooling module<br>——————<br>– Small air-cooled absorption chiller driven by recovered heat<br>• Advanced power conversion technology development that is market driven<br>———<br>• Fund development of liquid biofuels burner<br>—<br>• BOP (blowers, inverters, etc.) supplier commitment/ confidence/$<br>—<br>• Fund development of low cost grid connect that allows pre-certification of installer<br>• Paradigm shift heat exchanger designs – low cost (rotating new materials)<br>• Computer tech block: Thermo-electric Heat exchanger<br>– Boiler<br>– Furnace<br>– Absorption | • R&D on system integration elect/heat/cool<br>————————<br>– Engine generator with heat driven chiller<br>• Integrate storage into the system (Develop specs for thermal and electric)<br>——<br>• Product engineering<br>—— | • Develop system model and useful to develop control options<br>—————<br>– Design of control system to optimize the production and utilization of heat and power on a real-time basis<br>• Design activity to transfer concept into a reliable, mass produced "appliance" that can be sold, installed and maintained in a residential setting<br>• Engine driven compression heat pump with secondary electric generation<br>—<br>• Opportunity for identification and evaluation of novel concepts. SBIR? | • Fund pilot programs 10-100's of units to consortia<br>—————<br>– Have consumers evaluate<br>• Completion of full system prototypes, with high performance, which can be field tested<br>————<br>• Demo house on mall in DC<br>———<br>• Environment performance testing/documentation<br>——— | • Develop tech standards for connection of devices<br>———<br>• Specify methods to value/rate residential CHP performance<br>———<br>– Develop of a seasonal efficiency rating procedure application specific | • Fund effort for consortium<br>——<br>• Develop of appropriate business models<br>—<br>• Fund market assessment to consortia |

## TABLE 5.3 PATHS FORWARD

| TOP PRIORITY NEED | "SOUNDBITE" DESCRIPTION | TASKS | PARTICIPANTS | IMMEDIATE NEXT STEPS |
|---|---|---|---|---|
| • Develop residential scale cooling module | • Recycled heat driven cooling | • Develop specifications<br>Cooling load<br>Thermal energy needs<br>Configuration<br>Prime mover performance<br>Electric<br>Parasitics<br>Thermal availability<br>• Select cooling technology<br>Absorption or Adsorption<br>Desiccant<br>ERV<br>• Design/ lab prototype/ preliminary model and cost determination<br>• System integration<br>• Product prototype<br>• Field test demo<br>• Commercialization | • Team effort- Cooling component developer, lead system integrator, DFM and cost experts, and utility/commercialization partner | • Near-term RFP<br>• This is a pacing technology |
| • Systems integration (electric/heat/cooling) R & D | • Proof of concept of a residential packaged unit combining heat, power, cooling, and thermal storage, using off –the-shelf components | • Define power source<br>• Identify AC/dehumidification equipment, controls, and fuel source<br>• Assemble components<br>• Lab/field test | • Power source company<br>• AC/ Dehumidification company<br>• Controls company<br>• Solar company<br>• Integrator<br>• Utilities | • RFP |
| • Develop system model useful to develop control option and evaluate performance | • System Models | • Develop time-dependent, modular system model<br>Load following/matching<br>Control options<br>Economics<br>• Apply to candidate system<br>• Validate | • Team- Industry, National Labs, University, Industry Association | • Specify model requirements<br>Technology options<br>Model fidelity<br>Time resolution<br>Economic uncertainty |
| • Fund pilot programs (10-100's of units) to consortia and have consumers evaluate | • Residential Micro-CHP field demonstration and evaluation program | • Select technology<br>• Develop test program matrix<br>• Match technologies with location and markets<br>• Ensure field prototypes are ready<br>• Select field sites<br>• Coordinate with local utilities<br>• Define program costs | • Technology vendor<br>• DOE<br>• Test site "owner"<br>• Local utilities<br>• Field test "entity"<br>• Building contractor/appliance installer | • Solicit info from vendors<br>• Evaluate readiness and applicability of each<br>• Develop schedule<br>• Award contract |

| | | | | |
|---|---|---|---|---|
| | | • Performance evaluation<br>• Tech transfer | | |
| • Completion of full system prototypes with high performance, which can be field tested | • Micro-CHP full system development | • DOE solicitation definition<br>• Select teams<br>• Market analysis/define product target<br>• Develop “alpha” versions of complete systems<br>• Lab evaluation of complete system<br>• Design integration<br>• Controlled field tests<br>• Performance analysis extrapolation to a broad range of applications<br>• Identify further technology development needs<br>• Re-evaluate market potential and performance targets | • Industry led teams focused on specific product development<br>• Inter-team committees dealing with uniform product requirements, field/lab test protocols, standards, performance rating and labeling | • DOE solicitation<br>• ASHRAE symposium<br>• Standard development |

# Chapter 6.  Paths Forward

It is important that Micro-CHP systems be recognized as appliances. They need to be plug–and-play systems that can be easily installed and operated in any residence.  However, system performance needs to be understood. Well defined metrics must be established for efficiency, environmental performance and cost control.

Early adopters of Micro-CHP systems may include sectors and markets where reliability is needed most and when emergency/portable power situations exist, such as rural communities and vacation homes.

Since, heat and power are produced by Micro-CHP systems; they need to be designed to meet thermal loads of the house.  Unused heat must be discarded in an environmentally friendly manner.  Also, electric power must be available regardless how the system is designed.

Immediate next steps include communication and demonstration activities. Communication with utilities on the benefits of Micro-CHP systems needs to be initiated more effectively.  Workshops across the country would educate code officials, homeowners, builders, and government officials on Micro-CHP technologies and systems benefits.  The DER Road Shows, which present distributed generation equipment and applications to local code officials, provide a great platform to educate them as well on Micro-CHP.  Demonstrations in different climate zones and markets will provide crucial feedback on the performance of Micro-CHP appliances and will showcase their benefits.

# Appendix A.  Participants

Advanced Mechanical Technology, Incorporated (AMTI)
*Joseph Gerstmann*

British Gas
*Adrian Richardson*

Brookhaven National Laboratory
*Tom Butcher*

CANMET Energy Technology Center
*Evgueniy Entchev*

Climate Energy, LLC
*Rui Afonso, Eric Guyer, Thomas Reed*

Columbus Circle Power Systems, LLC
*Charles Garland*

Consumer Energy Council of America
*Christian Murphy*

EA Technology
*Jeremy Harrison*

ENATEC Micro-Cogen, b.v.
*Leon Gielen*

Energetics, Incorporated
*Dan Brewer, Rich Scheer, Tom Tarka*

Energy Co-Opportunity
*Kamyar Zadeh*

EXERGY Partners Corporation
*Rich Sweetser*

Gas Appliance Manufacturers Association
*Evan Gaddis, Mark Kendall, David Sutula*

Gas Technology Institute
*Charles Berry*

Honda Research and Development
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ICF Consulting
*Rick Fioravanti*

Lennox Industries Applied Research
*Robert Alvarez*

Marathon Engine Systems
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National Renewable Energy Laboratory
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Navigant Consulting
*Ed Barbour, Dave Ahrens*

Northeast-Midwest Institute
*Suzanne Watson*

Oak Ridge National Laboratory
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Plug Power
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Power Equipment Associates, Ltd.
*Ted Bronson*

Power Plan Energy, LLC
*Michael Hopper*

Solargenix, LLC
*Tom Henkel*

Stirling Technology Company
*Ray Erbeznik*

TIAX, LLC
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U.S. Department of Energy
*Ron Fiskum, Pat Hoffman, Merrill Smith*

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*Scott Hutchins*

U.S. Department of Energy- Chicago Operations Office
*Dale Dietzel*

U.S. House of Representatives
*Eli Hopson, Tina Kaarsberg*

United Technology Research Center
*Tom Rosfjord, Michael Sahm*

University of Maryland
*Reinhard Radermacher*

# Appendix B. Agenda

## *National Micro-CHP Technology Pathways Workshop*

*The Greenbelt Marriott*
*Greenbelt, Maryland*
*June 11-12, 2003*

## *Agenda*

### Wednesday, June 11

7:30 am **Continental Breakfast and Registration**

8:30 am **Opening Plenary Session**

- Welcome and Introductions, *Ronald Fiskum, U.S. Department of Energy*
- Opening Remarks, *Pat Hoffman, U.S. Department of Energy*
- Technology Pathways Workshop Gameplan and Logistics, *Rich Scheer, Energetics, Incorporated*

9:00 am **Experience with Micro-CHP Around the World**

- Europe, *Jeremy Harrison, EA Technology*
- Japan, *Bill Bezilla, Honda Research and Development*
- Canada, *Evgueniy Entchev*, *CANMET Energy Center*

Moderator: *Rich Sweetser, Exergy Partners*

Panelists will discuss Micro-CHP in various countries. They will discuss technologies, as well as the policy and market infrastructure that has encouraged or inhibited Micro-CHP systems.

10:15 am **Break**

| | | |
|---|---|---|
| 10:30 am | **United States Micro-CHP Environment** | |

10:30 am **United States Micro-CHP Environment**

- Building America: Innovations in America's Housing, *Ren Anderson, National Renewable Energy Laboratory*
- Markets and Climates, *Steve Fischer, Oak Ridge National Laboratory*
- Technologies for Micro-CHP, *Tom Butcher, Brookhaven National Laboratory*

Moderator: *Suzanne Watson, Northeast Midwest Institute*

The National Renewable Energy Laboratory will discuss the Building America program, which is a private/public partnership that provides energy solutions for production housing. The program provides new product opportunities to manufacturers and suppliers and implements innovative energy-and material-saving technologies. Oak Ridge National Laboratory will present an assessment of residential electric, heating, and cooling load profiles and building techniques for the different climate zones across the United States. Brookhaven National Laboratory will give an overview of the technologies that can be used in Micro-CHP systems.

11:30 am **Review of the Overall Goal:** ***To develop clean, cost-effective, commercially available Micro-CHP systems in the U.S. residential marketplace by 2010.***

12:15 pm **Lunch**

1:15 pm **Breakout Session #1: Technology Cost and Performance Cost Targets-** What technology cost and performance targets have to be achieved to develop clean, cost-effective, commercially available Micro-CHP systems in the United States residential marketplace by 2010?

Participants will be divided into one of three breakout groups: blue, orange, or yellow. The breakout groups will operate in parallel; each group will answer the same question.

2:45 pm **Break**

3:00 pm **Breakout Session #2: Needs-** What research, development, demonstration and technology transfer needs to be done to the reach the technology cost and performance targets? When should the actions take place?

4:45 pm **Adjourn**

5:15 pm **Bus Leaves for Reception and Tour of the Chesapeake Building**
***Reception Sponsored by: Climate Energy and VectorCoGen***

The Chesapeake Building at the University of Maryland is the home of the Integrated Energy Systems Test Center. It is designed as a research facility that explores the intricacies of integrating advanced power generating equipment, such as microturbines, with waste heat activated technologies such as absorption chillers and desiccant systems. Participants will tour the two different CHP systems installed at the facility and then join colleagues for a reception and exhibitor showcase adjacent to the building (outside, weather permitting).

8:00 pm **Return to the Hotel**

## Thursday, June 12

7:00 am **Continental Breakfast**

8:00 am **Breakout Session #3: Paths Forward-** What are the pathways to accomplish the top priority needs?

9:30 am **Prepare Breakout Session Presentation**

10:00 am **Break**

10:15 am **Closing Plenary**

- Breakout Session Group Reports
- Common Themes
- Closing Remarks and Next Steps, *Ronald Fiskum, U.S. DOE*

Moderator: *Rich Scheer, Energetics, Incorporated*

11:45 am **Adjourn**